

ExoMars 2016

Entry Descent and Landing

Overview

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San Jose, CA
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Leila V. Lorenzoni
ESTEC EXM EDL Engineer
and

T. Blancquaert, O. Bayle, S. Langlois, T. Walloscheck (ESTEC)
M. Capuano, S. Portigliotti (TAS-I)



ExoMars Programme Objectives

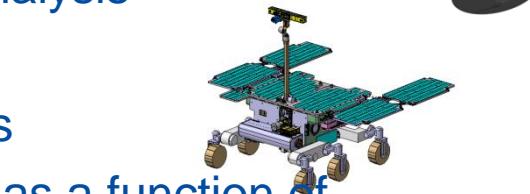
Technology Objective

- Entry, Descent and Landing of a payload on the surface of Mars
- Surface Mobility with a rover
- Access to the subsurface to acquire samples
- Sample acquisition, preparation, distribution and analysis



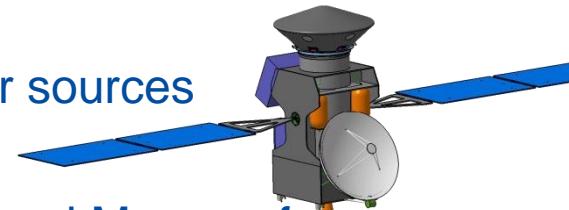
Scientific Objective

- To search for signs of past and present life on Mars
- To investigate the water/geochemical environment as a function of depth
- To study Martian atmospheric trace gases and their sources



Programmatic Objectives

- Support Mars proximity communication of international Mars surface assets



ExoMars Programme Overview

- Two missions launched in 2016 and 2018
 - The 2016 mission consists of a Trace Gas Orbiter (TGO) and an EDL Demonstrator Module (EDM)
 - The 2018 mission consists of a Rover accommodated inside a Descent Module carried to Mars by a Carrier Module
 - Large international cooperation with Roscosmos (ROS) and some contributions from NASA

esa 2016 Mission

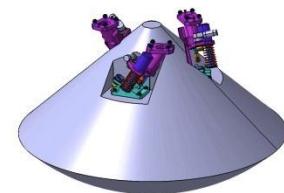
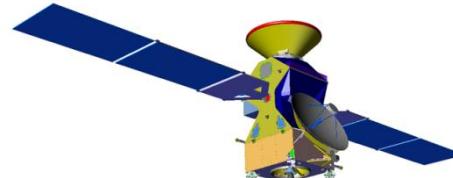


AND

esa 2018 Mission



Trace Gas Orbiter (TGO)



EDL Demonstrator Module (EDM)

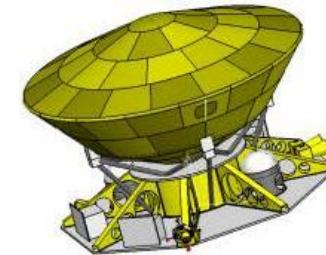


Science Operations Centre (SOC) @ ESAC (TBC)



Proton

Carrier Module & Descent Module



Rover + ROCC +
Lander Ops Centre

ExoMars 2016 Mission

LAUNCH

Jan 2016

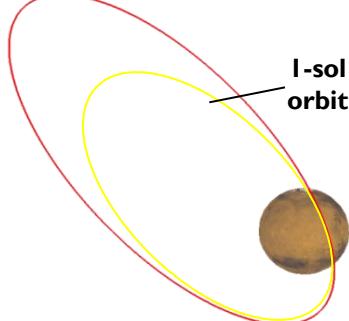


ExoMars SCC in launch configuration

TRANSITION TO 1-SOL ORBIT

4-sol

orbit



- (1) Inclination change to that of science orbit (74°)
- (2) Apoares reduction to 1 sol

INTERPLANETARY CRUISE

Launch
Jan 2016

Arrival
Oct 19th, 2016

Type II, $C_3 = 7.44 \text{ km}^2/\text{s}^2$

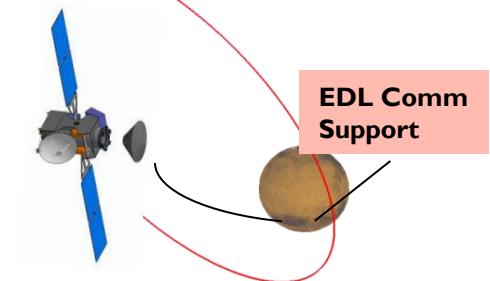
AEROBRAKING & SCIENCE PHASE

6-9 month
Aerobraking

Science & Relay
Orbit
(~400km
circular)

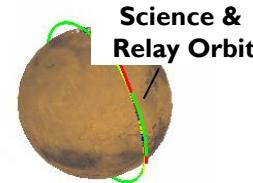
- (1) Aerobrake to final orbit
- (2) Start of Science Phase

APPROACH, EDM RELEASE & MOI



- (1) EDM released from the hyperbolic approach 3 days before MOI
- (2) Orbiter performs retargeting and MOI into 4 sol orbit

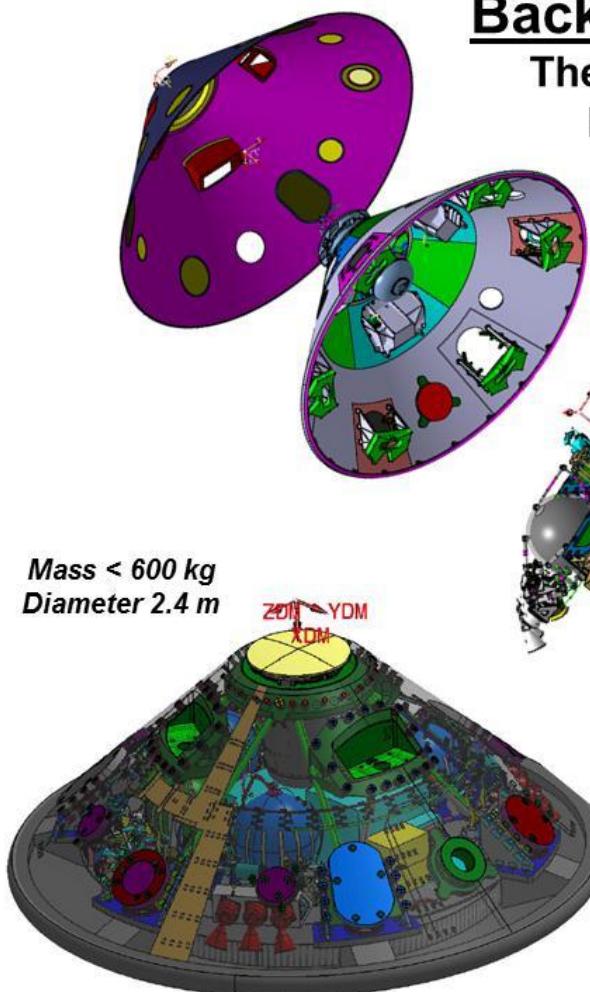
DATA RELAY PHASE



- (1) Data relay for 2018 Rovers starts in Jan 2019
- (2) Data relay capability for future Mars surface assets throughout 2022

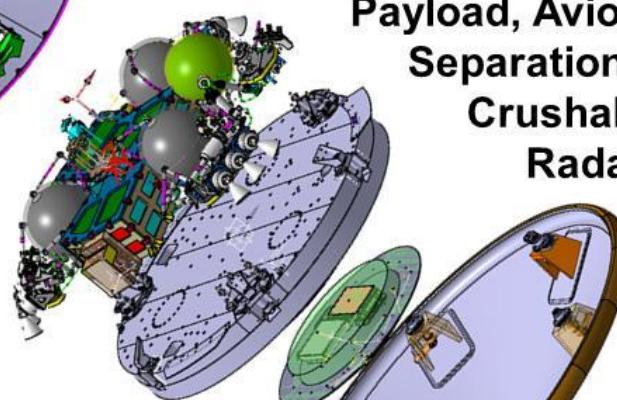
ExoMars (EXM)

Entry Descent and Landing Demonstrator Module (EDM) major components



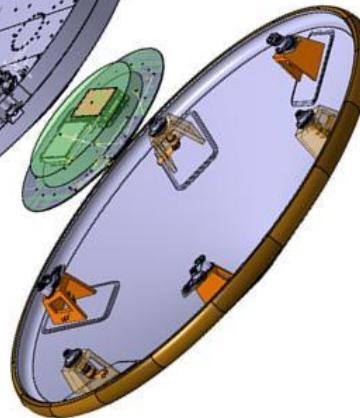
Back Shell

Thermal Protection System, Back Cover,
Back shield Instrumentation
Parachute System



Surface Platform

Payload, Avionics, Propulsion System
Separation Mechanisms
Crushable Structure
Radar Doppler Altimeter



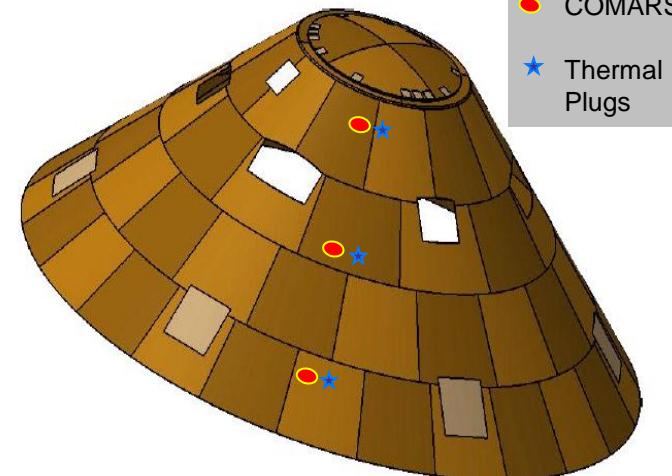
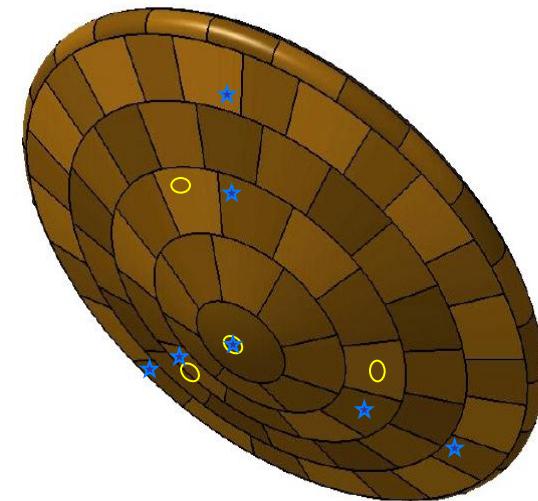
Front Shield

Front Shield Structure
Thermal Protection
System with
Instrumentation



EDL Engineering Measurements

- Entry Dynamics measured by functional GNC sensors
 - Inertial Measurement Unit → Accelerations & angular rates
 - Radar Doppler Altimeter and Velocimeter → Ground-relative motion
 - Sun Sensor → Inertial attitude before Entry
- Aerothermodynamics Sensors
 - Pressure sensors on Front Shield (x4)
 - COMARS+ (x3) to measure Pressure, Convective Heat Flux and Radiative Heat Flux TPS Sensors
 - Thermal plugs embedded in Front Shield (x7) and Back Shield (x3) TPS
- Parachute Inflation loads measured by IMU (100 Hz acquisition frequency)
- Impact loads measured by dedicated accelerometers



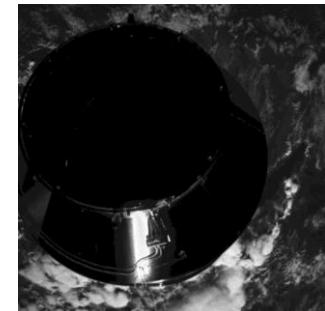
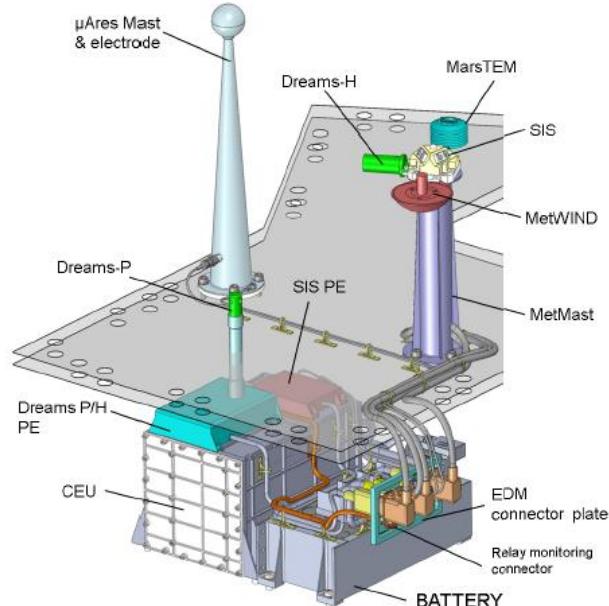
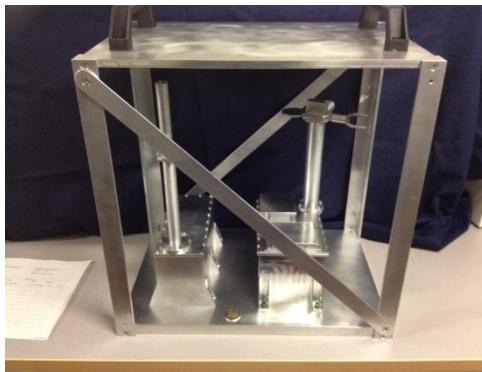
Legend:
○ Pressure Sensors
● COMARS+
★ Thermal Plugs

EDM Science

- Surface Payload – DREAMS (Dust characterisation, Risk assessment, and Environment Analysers on the Martian Surface)

➤ Sensors

1. MarsTem -- atmospheric T sensor (I)
2. DREAMS-P – atmospheric P sensor (Fin)
3. DREAMS-H – atmospheric humidity sensor (Fin)
4. MetWind – wind sensor (UK)
5. MicroARES – atmospheric electrical field sensor
6. SIS-Solar Irradiation Sensor



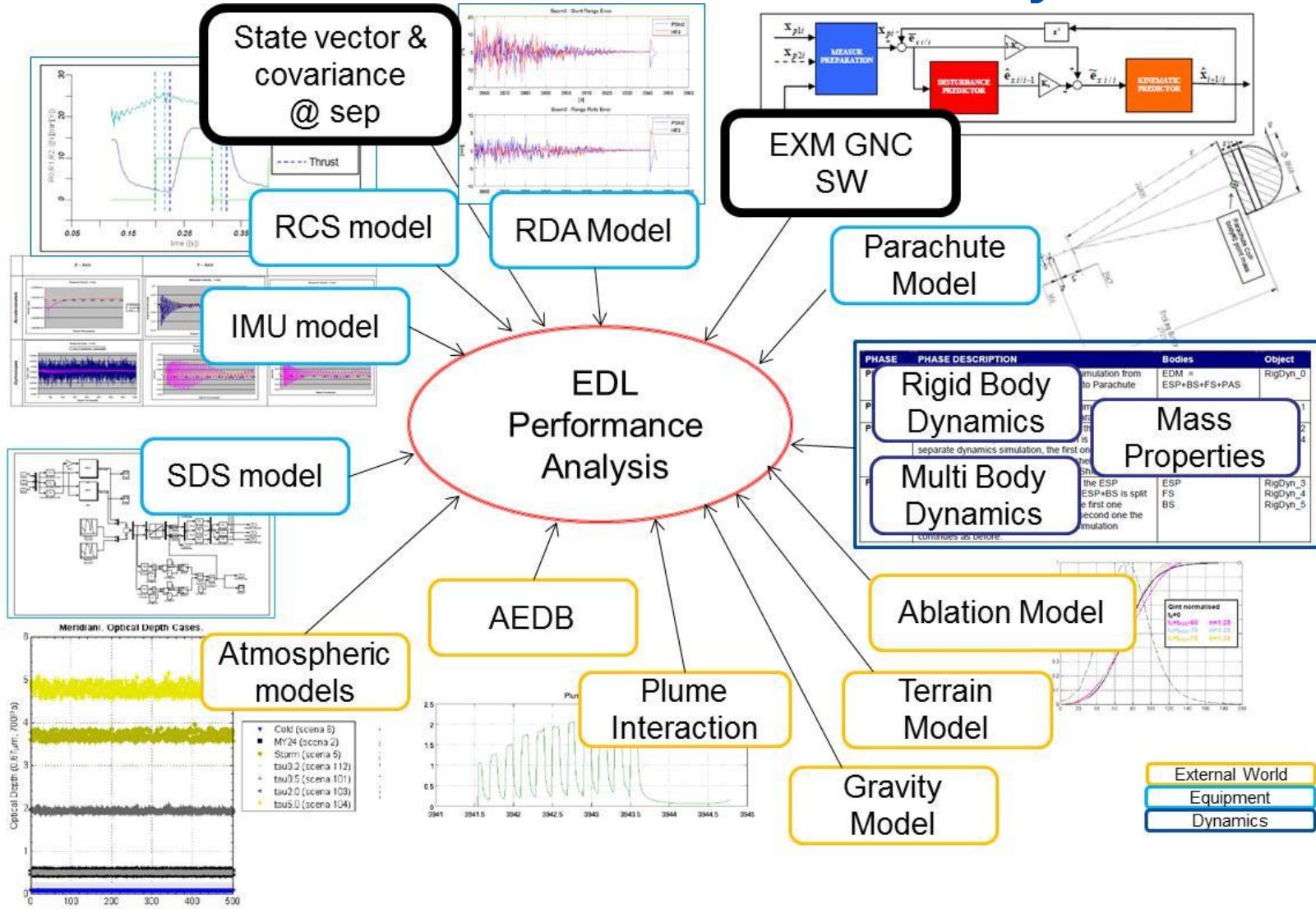
- DeCa: Descent Camera provided as Customer Furnished Item (HP Flight Spare)

- AMELIA (Atmospheric Mars Entry and Landing Investigations and Analyses)

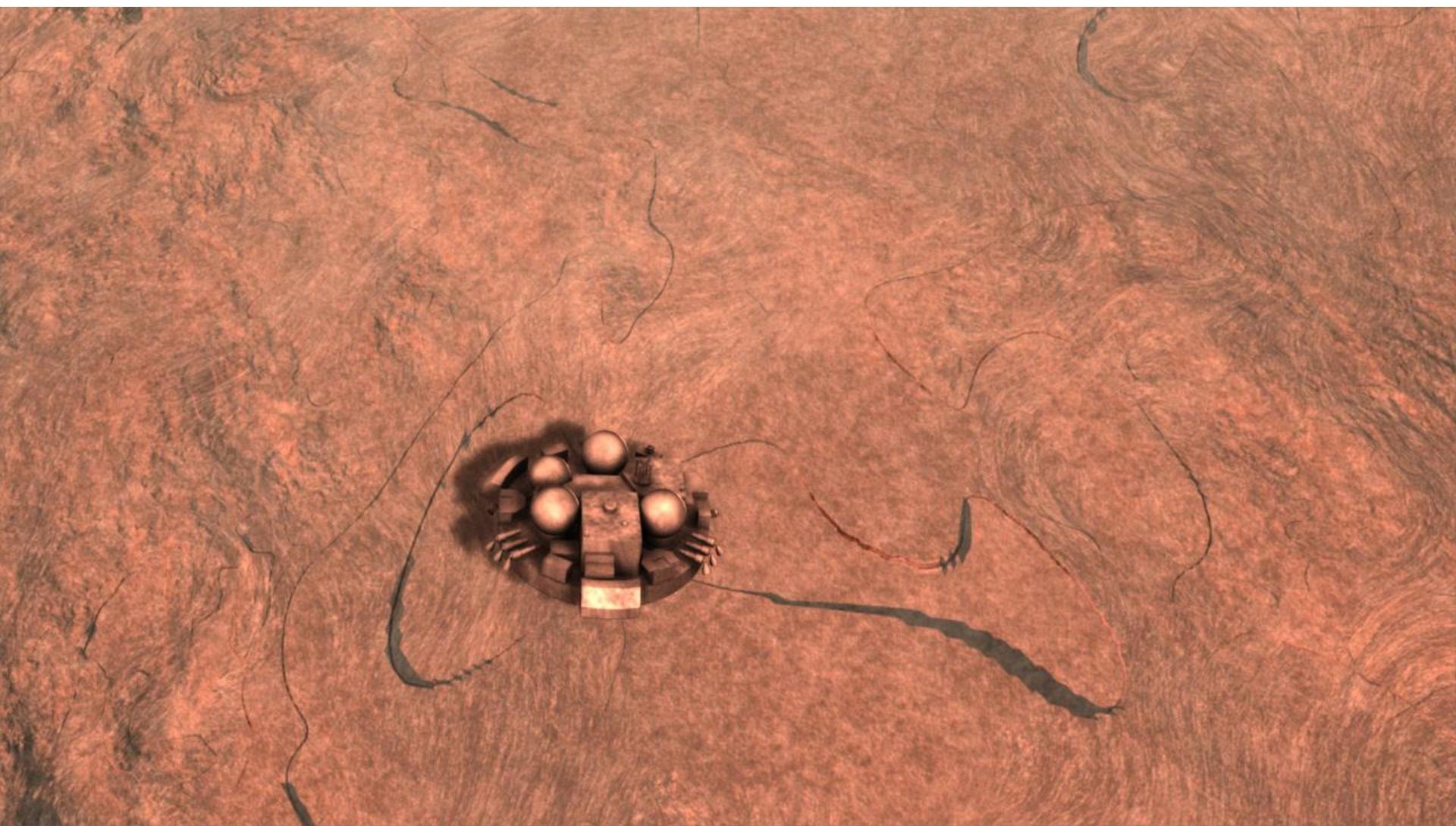
EDM EDL- Scientific analysis of data for:

- Deriving atmospheric profiles of density, temperature & pressure with fine spatial resolution
- Unveiling behaviour of the dusty Martian atmosphere – improve models for future missions usage

EXM EDL FE2E Simulator and EDL Performance Analysis



EXM EDL Sequence



EXM EDL Entry



ExoMars 2016 - EDM Entry



- State vector initialisation from TGO
- Spun up at 2.5 rpm by separation mechanism
- Separation from TGO for hyperbolic entry
- Hibernation for ~3 days of coasting
- Wake-up
- State vector reinitialisation
- Start Transmission of essential telemetry to TGO



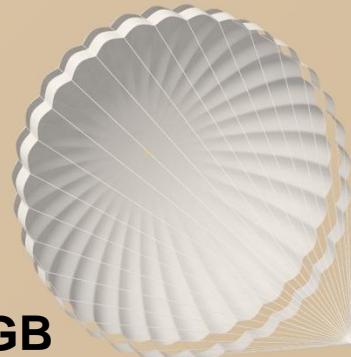
- Entry into Martian atmosphere
 - ❖ Ls=244 ° (GDS)
 - ❖ EFPA=-12.4 deg +/- 0.22 deg
 - ❖ Velocity= 5.68-5.83 km/s
 - ❖ Landing Target 1.82S, 6.15W

EXM EDL Descent



➤ Deploy Supersonic 12 m DGB

- ❖ g-activated
- ❖ Mach 1.85-2.1
- ❖ Dynamic pressure < 980 Pa
- ❖ Inflation load <69 kN



➤ Front Shield Jettisoning

- ❖ Para deploy + 40 sec

➤ Activate RDA for local Navigation



➤ Back Shield Jettisoning

- ❖ Vertical velocity 60-85 m/s
- ❖ Altitude 600-1250 m AGL



3. Parachute deployment

4. Front shield jettison

5. Surface platform separation

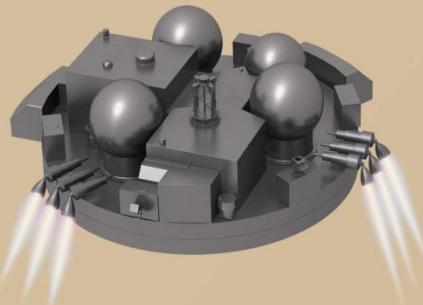
EXM EDL Landing

- Thrusters Warm Up
- Back Avoidance Manoeuvre
- Final Braking

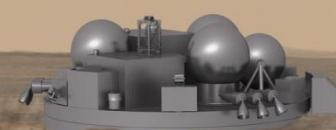


- Switch Off Thrusters

- ❖ Altitude 1.8 +/- 1 m AGL
- ❖ Vertical velocity within +/- 0.8 m/s
- ❖ Horizontal velocity +/- 1.6 m/s
- ❖ Off Vertical Angle < 7° deg
- ❖ Angular rate < 8.8 deg/s



- Touchdown
- ❖ Landing Accuracy
50kmx7.5km
- ❖ LST: 14.38-14.47
- ❖ Activate Surface Payload
- ❖ Initiate Operation Sequence
for UHF Comm session
- ❖ Enter hibernation

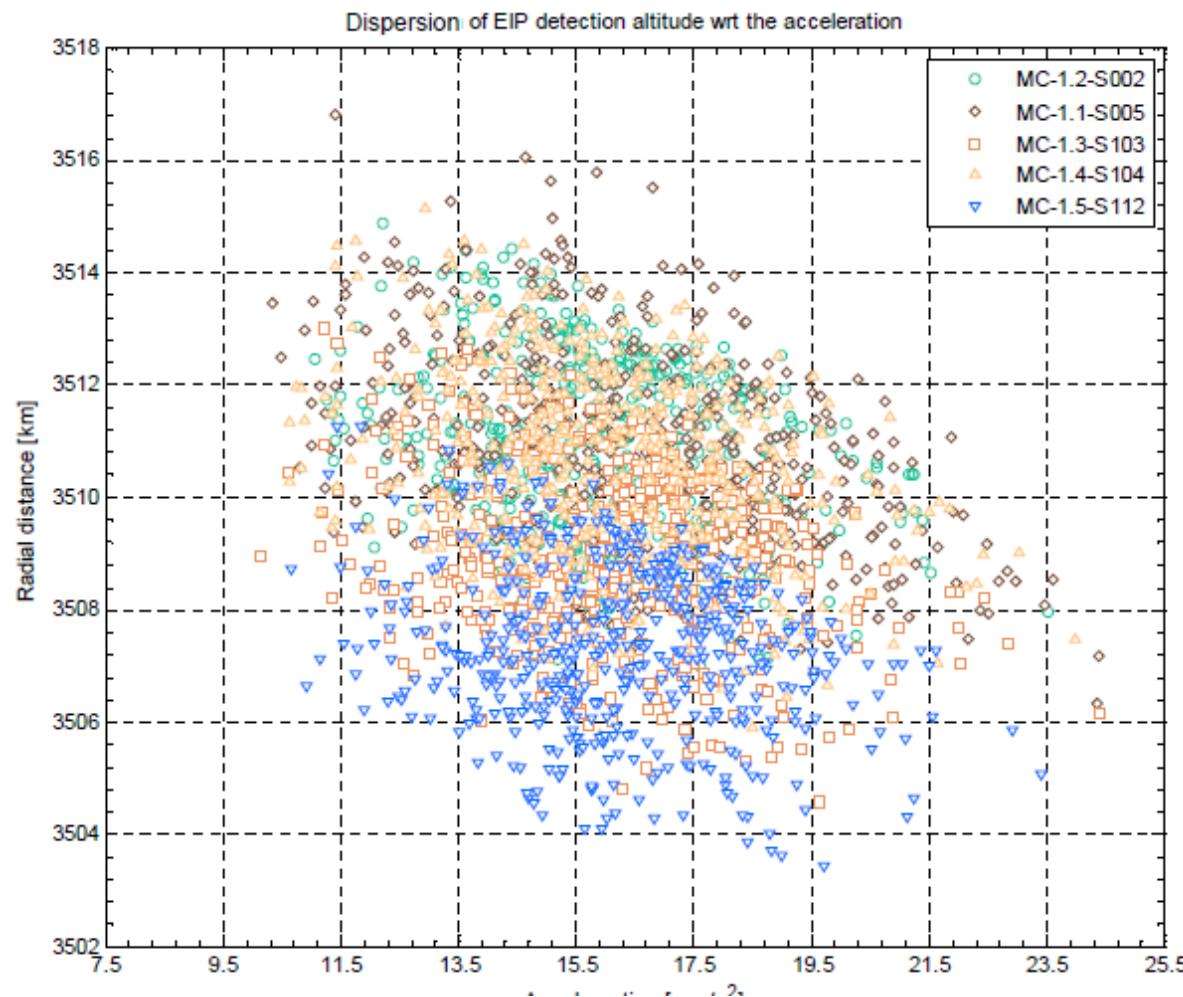


6. Engine firing

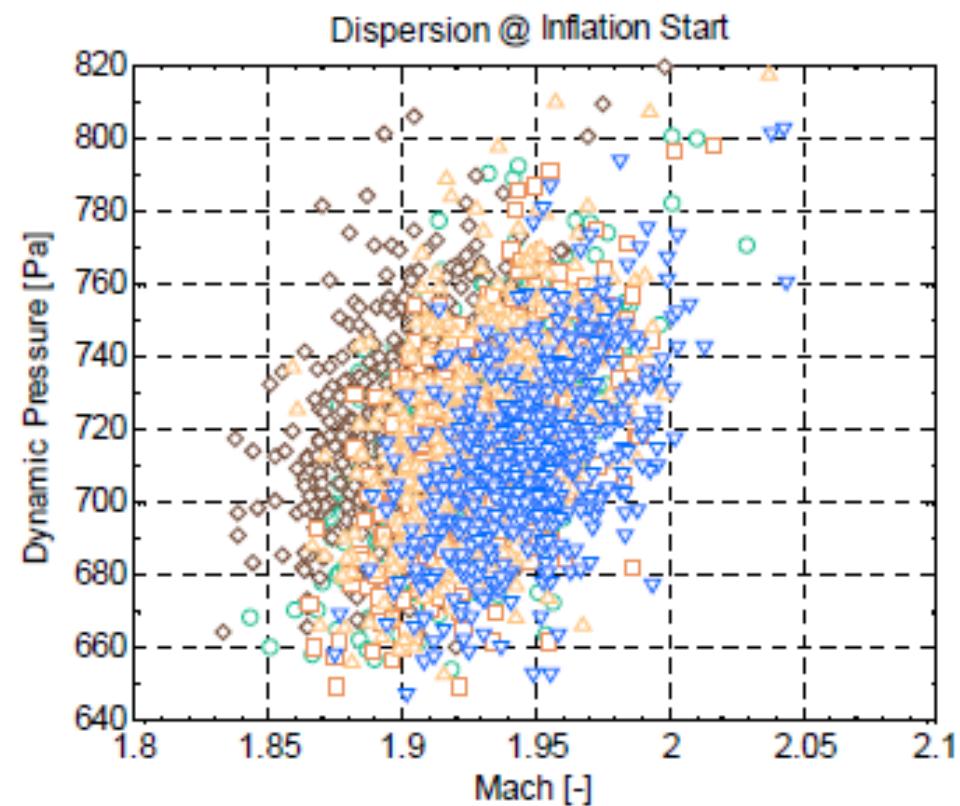
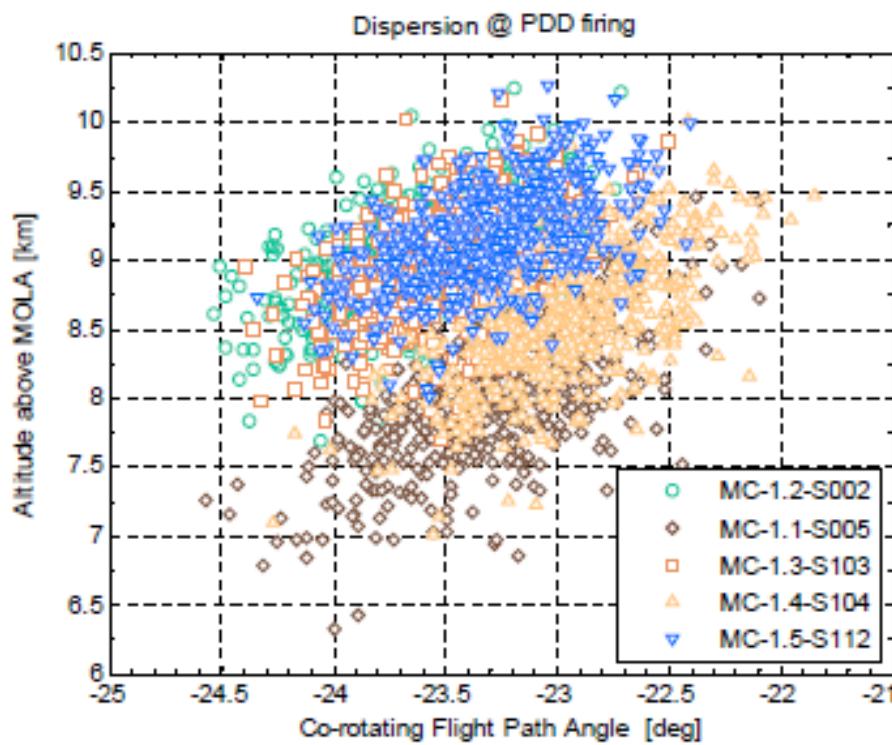
7. Descent to surface

8. Touchdown

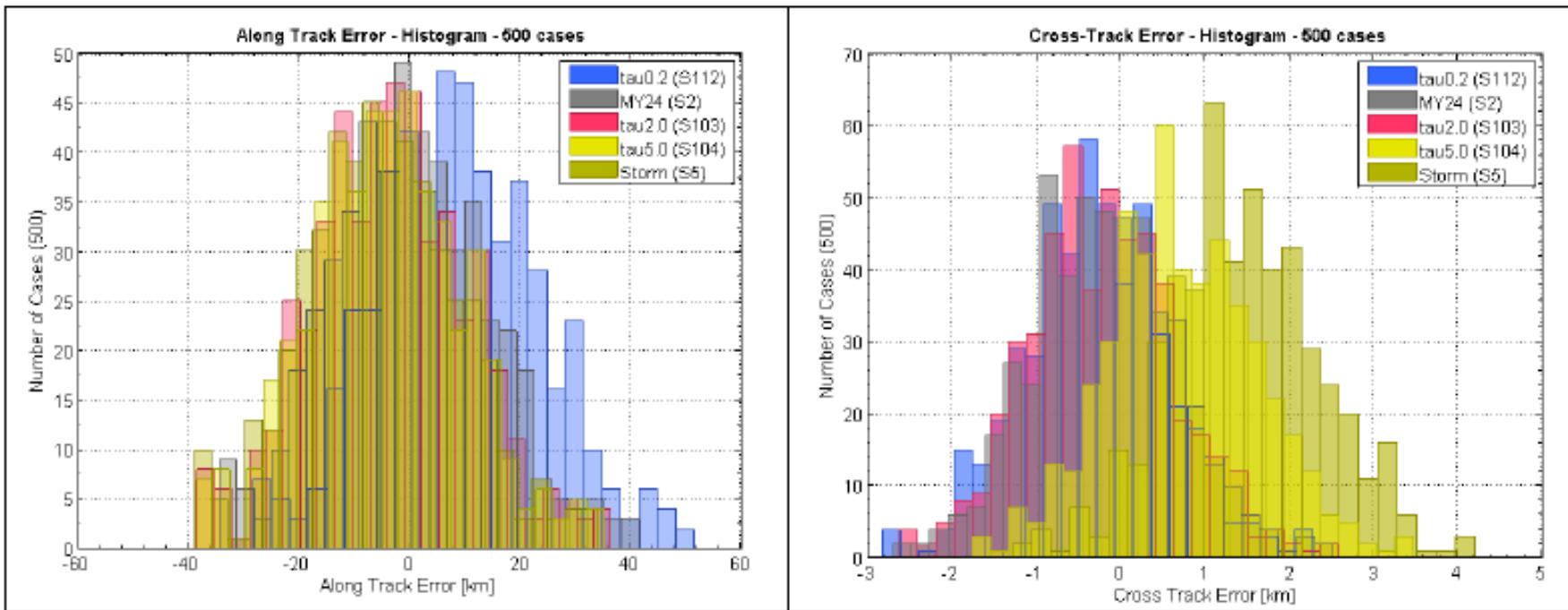
Dispersions of EIP Detection



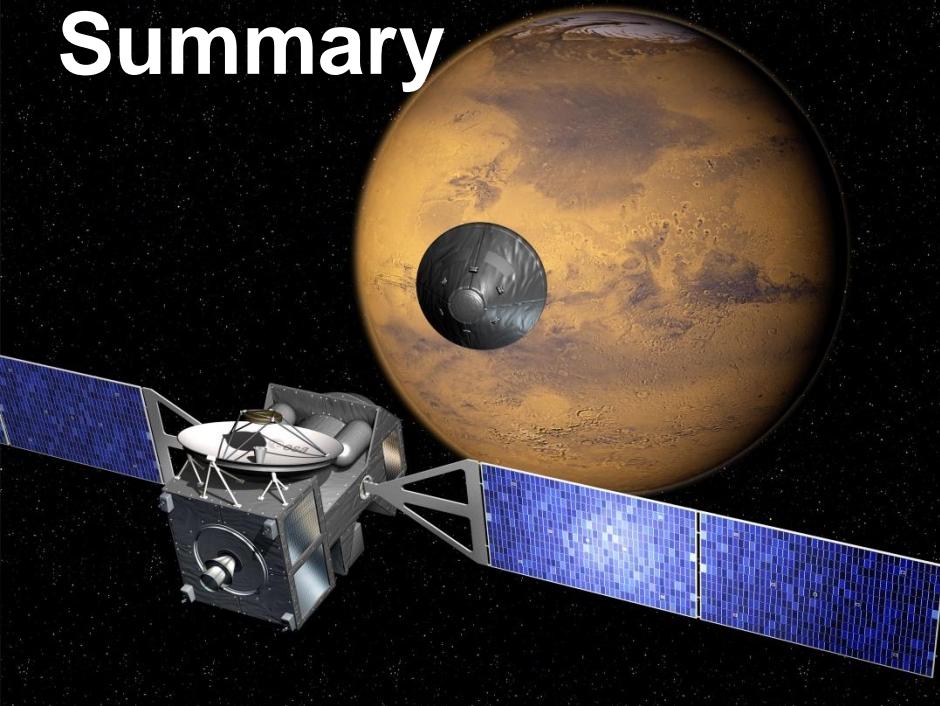
Dispersions at Parachute Phase starts



Dispersions of the Landing target



Summary



1- Separation from TGO on hyperbolic trajectory

- ✓ 3 days before Mars atmospheric entry
- ✓ Spin-up at 2.5 rpm for attitude stabilisation (provided by separation mechanism)

2- Coast Phase

- ✓ On-board systems in hibernation mode shortly after separation, awaken 1 hour prior to atmospheric entry



3- EDL Phase

- ✓ Ls 244 deg, within Global Dust Storm Season
- ✓ Landing Site at Meridiani Planum with landing ellipse 100 Km x 15 Km, 3σ
- ✓ UHF proximity link with TGO for transmission of essential telemetry

4- Surface Phase

- ✓ On-board systems in hibernation mode shortly after landing, awaken for Comms sessions with NRO
- ✓ Flight and Surface Payload data upload via UHF proximity link with NRO